MEANS AND MIDRANGES OF RELATIVE HUMIDITY

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ABSTRACT

Daily midranges (average of highest and lowest) of relative humidity overestimate the true 24-hr. mean by about 3 percent at humidities of less than 15 percent and underestimate it by an equal amount at humidities over 85 percent. Daily readings at five United States stations in January and July, 1961–63, and at Burbank for all months, 1961–63, were studied.

1. INTRODUCTION

Relative humidity, despite its many limitations, is the measure of atmospheric moisture content most used by the general public. Temperature and relative humidity are reported incessantly by radio announcers, and published in most newspapers. Often a day's highest and lowest values of relative humidity are presented, along with the maximum and minimum temperatures.

Although Blanc [1] reported "no known plans to compute daily means based on daily maximum and minimum values" of relative humidity, such midranges have been published in the *Local Climatological Data* for at least one Weather Bureau station (Burbank). This practice is an obvious extension of the standard procedure of calling the temperature midrange the "average" temperature of the day. The validity of such an approximation for humidity is the subject of this paper, begun by students in a climatology class and continued by the junior author under supervision of the senior author.

Despite its widespread popular use, relative humidity has not been studied extensively in the United States. Because it depends on air temperature as much as on moisture content, relative humidity is less used in meteorology than other more stable measures, such as dew point and mixing ratio.

2. HISTORICAL

Half-a-century ago, Day [3] with the help of Marvin and Kincer analyzed five series of psychrometric observations:

a. at 2 p.m. local time at 64 stations, 1876–1880;
b. every 4 hr. from 7 a.m. to 11 p.m., EST, at 11 stations, 1881–1886;
c. at 8 a.m. and 8 p.m., EST, at 173 stations, 1889–1913;
d. every 2 hr. at 11 stations, 1911–1915.

From the fourth set, he computed the monthly means of the bi-hourly observations, and offered a table of "corrections to be applied to the average monthly values of the relative humidities at 8^a and 8^p (75th meridian time). . . to reduce the latter values to true 24-hour means." For eight of the stations, all "corrections" were negative, up to as much as 5 percent in early autumn. In one month each at Boise (Feb.) and San Francisco (Dec.), the corrections were positive, while all other corrections were zero or negative. Fresno had three positive corrections (in winter), the rest zero or negative, while at Sacramento winter corrections were positive, summer corrections zero. Day's data are given in table 1.

Similarly, Cox and Armington [2] declared that "average values for mean relative humidity . . . based . . . upon observations taken at 7 a.m. and 7 p.m. are somewhat higher than the mean of observations taken at each of the twenty-four hours of the day would give, and also slightly higher than the mean obtained from the maximum and minimum relative humidity of the successive days." The average of bi-hourly values was higher than the 7 a.m. and 7 p.m. average in each month at Chicago, May 1911 to April 1912.

These times are Central Standard Time, corresponding to the 8 a.m. and 8 p.m. EST times cited by Day. But they actually refer to synoptic observations made half-an-hour earlier, so that in some tabulations they are listed as 7 a.m. and p.m., as in the Climatological Record Books (Hagarty [4]) for each of the three periods covered by those bound volumes, 1871–1910, 1911–30, and 1931–50; in the third volume a page was added for the local noon observation, begun in 1918 and abolished in 1938.

Blanc [1] compared the 24-hr. means of relative humidity with those based on the four synoptic observations, but did not investigate midranges of humidity, although he did so for temperature and dew point. Five years (1955–59) of data for mid-season months showed that the synoptic-hour means were within 1.3 percent of the 24-hr. means at nine stations, the greatest departures being +1.2 at Miami and −1.3 at Salt Lake City, both in October.

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TABLE 1.—*Difference between mean relative humidities from bi-hourly observations and from averages of observations at 0800 and 2000* EST *(From Day [3], table 5)*

Station and Period	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Burlington, Vt., July 1911 to Apr. 1916	−2	−2	−2	−1	0	−1	−1	−2	−3	−3	−3	−2
Ithaca, N.Y., Nov. 1911 to Dec. 1915	−2	−2	−3	−3	−2	−1	−2	−4	−5	−4	−3	−2
Columbus, Ohio, May 1911 to Mar. 1916	−2	−2	−2	−2	−1	−1	−2	−2	−2	−2	−2	−1
Grand Rapids, Mich., July 1912 to Apr. 1916	−1	−2	−2	−2	−2	−1	−1	−3	−4	−5	−4	−2
Chicago, Ill., May 1911 to Apr. 1916	−1	0	−2	−2	−2	−1	−1	−1	−2	−2	−2	−1
Springfield, Ill., Feb. 1912 to Apr. 1916	−1	−2	−2	−2	−2	−2	−2	−3	−2	−2	−3	−1
St. Louis, Mo., May 1911 to Nov. 1914	−2	−1	−2	−2	−1	−2	−1	−2	−2	−2	−2	−1
Sheridan Wyo., July 1913 to Apr. 1916	−2	−2	−1	−2	−1	−2	−2	−4	−4	−3	−4	−2
Boise, Idaho, May 1911 to May 1915	0	+2	−2	0	−2	−1	−2	−2	0	0	0	0
Sacramento, Calif., July 1913 to Apr. 1916	+1	+2	+2	+1	0	0	0	0	0	+1	+2	+3
Fresno, Calif., May 1912 to Apr. 1916	+1	+1	0	−2	−2	−2	0	0	0	−1	−1	+1
San Francisco, Calif., May 1911 to Apr. 1916	0	0	−1	−1	−2	−2	−1	−1	−2	−3	−1	+1

3. SUMMARIES

Average relative humidity in each month at 8 a.m. and 8 p.m., and at local noon, at Weather Bureau first order stations was given in the 1930 "Climatic Summary of the United States" (called *Bulletin* W), but not in its 1952 Supplement. Similar values were presented regularly (through 1949) in the *Monthly Weather Review*, in the Bureau's monthly and annual summaries for individual weather stations (*Local Climatological Data*), and in special tabulations such as "Fifty Years' Weather in Kansas City, Mo., 1889–1938" (Hamrick and Martin [5]). Maps of mean relative humidity at 8 a.m., noon, and 8 p.m. in January and July were published in "Climate and Man" [6], and widely reprinted (e.g., Visher [8]).

The increase in the number of synoptic observations to four per day was reflected in tabulations of mean monthly relative humidity, at each observation time, in the *Local Climatological Data* for individual stations, in supplementary tables in the monthly state *Climatological Data*, and in the "Climates of the States", issued in 1959 as *Climatography of the United States* No. 60–xx. Monthly averages of these four daily values are given in the Bureau's *Climatological Data, National Summary*. They also appear on monthly maps of average relative humidity (on a 1961 sheet of the *National Atlas*), based on readings at 1:30 and 7:30 a.m. and p.m., EST, at 236 stations with at least 20 years of data up to 1959.

Supplements to the *Local Climatological Data* for stations taking 24 observations per day began as "Special Meteorological Data" in 1949, listing hourly values for all elements, including relative humidity, in chronological order, with no totals or averages. Summaries gave frequencies of occurrence of relative humidity, by 10-percent (or other) classes, for each hour of the day, and also of various temperature-humidity combinations for three wind speed intervals.

In 1961, a summary (denoted Table G) was added to these Supplements, giving "24-Hour Averages" of various elements, including relative humidity, for each day of the month. These averages afford ready comparison, for the first time, of the 24-hr. mean relative humidity with that based on two or four synoptic observations, and on the midrange of the hourly humidities. Daily data for the first three years of these publications (1961–63) [7] were used for the present study.

4. DATA

Six stations were used for this study: Burbank, Calif.; Las Vegas, Nev.; Great Falls, Mont.; Wichita, Kans.; Jacksonville, Fla.; and Nantucket, Mass. These were chosen because of their diversity in climate, ranging from the desert situation at Las Vegas to the maritime climates of Jacksonville and Nantucket. Lying somewhere in between these extreme examples of dry and wet conditions are the continental-type stations of Great Falls and Wichita and the modified maritime station at Burbank.

Typical of most inland locations, Great Falls and Wichita undergo fluctuations in humidity with changing wind directions during all seasons. In the winter both stations are subject to outbursts of dry polar air with accompanying falls in humidity. Whereas Great Falls is often influenced by the flow of modified Pacific air onto the continent, Wichita is commonly under the dominance of a strong anticyclonic flow which produces southerly winds of varying moisture content.

Burbank, like many stations near the Pacific Coast, is exposed to direct inflow of moist ocean air which has been slightly altered by its path across land. In addition, its climate is affected to a variable degree by the dry Santa Ana winds, especially in autumn and winter, which may alter the average relative humidity of a given month by as much as 20 percent.

The effect of location on humidity is readily apparent in table 2. At maritime stations (Burbank and Nantucket and to some extent Jacksonville) average humidity increases from January to July, while at inland stations it

TABLE 2.—*Means and standard deviations of daily midrange of relative humidity, January and July, 1961–63 (in percent)*

Station	January		July	
	Mean	S.D.	Mean	S.D.
Burbank, Calif.	47.4	20.0	64.9	8.0
Las Vegas, Nev.	38.3	13.0	17.6	11.1
Great Falls, Mont.	60.0	15.8	48.9	11.3
Wichita, Kans.	70.6	12.4	64.6	10.3
Jacksonville, Fla.	71.6	11.0	72.7	5.7
Nantucket, Mass.	73.5	14.0	83.0	15.7

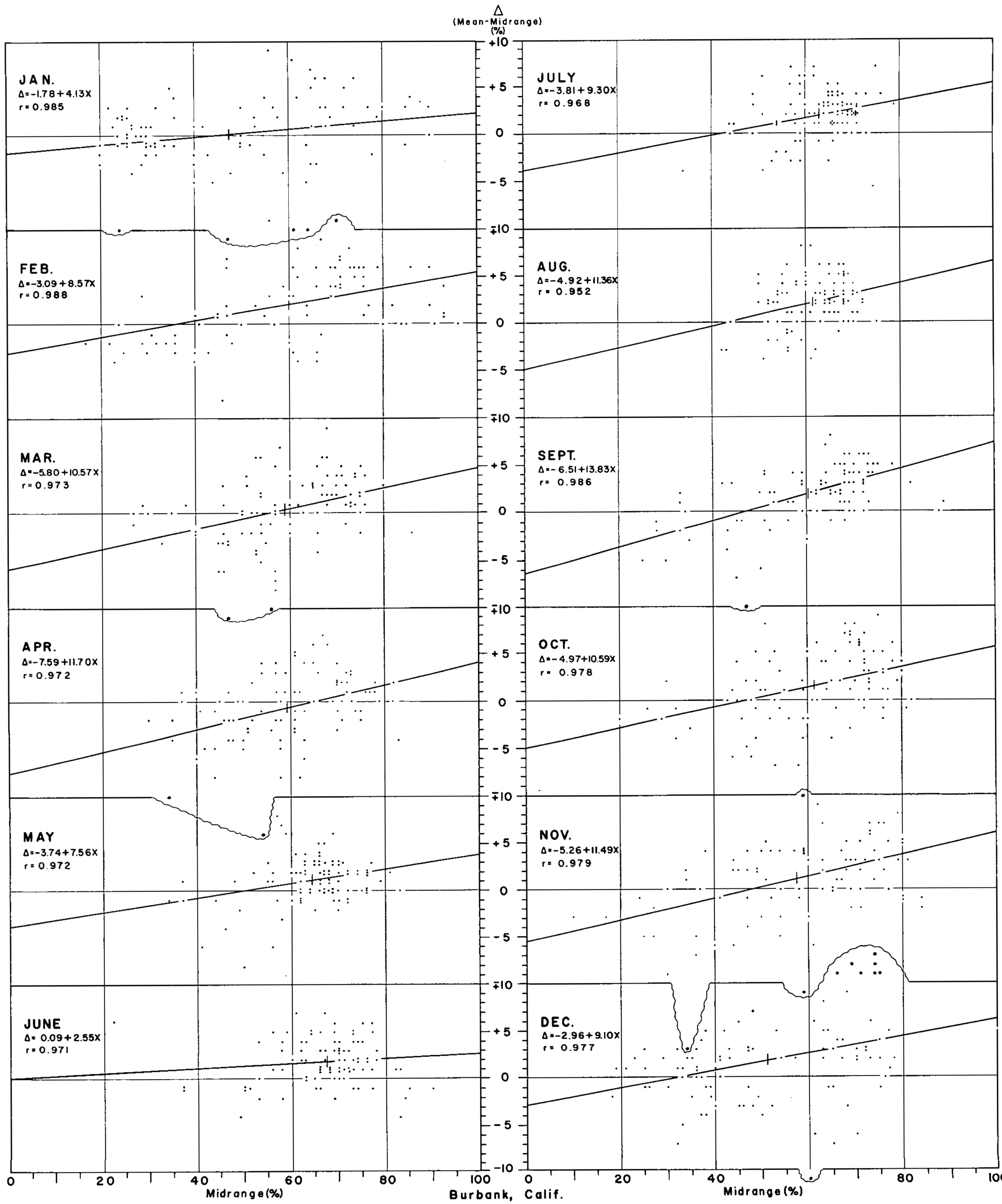

FIGURE 1.—Mean-midrange difference of daily relative humidity vs. midrange at Burbank, Calif., by months, 1961–63.

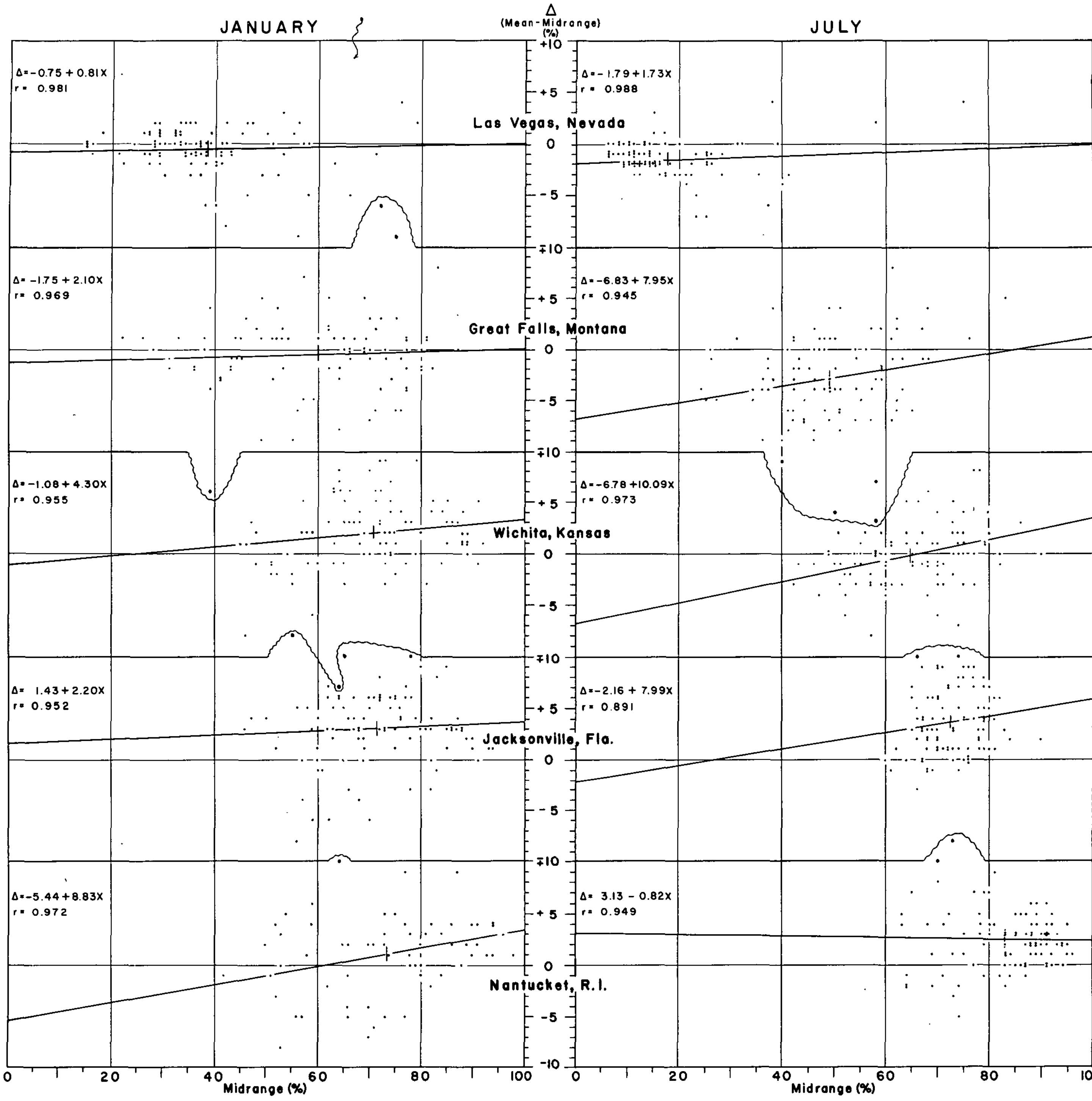

FIGURE 2.—Mean-midrange difference of daily relative humidity vs. midrange for 5 stations, January and July, 1961–63.

decreases. The seasonal increase at Burbank during these three years is larger than the long-term mean, in which the relative humidity is close to 60 percent in January.

To reduce the complexity of the study, data for only January and July were used at five stations. For Burbank, however, each month was investigated in an attempt to depict overall seasonal trends. The limitation to only two months for the five stations severely curtails the validity of conclusions concerning seasonal trends of the mean-midrange relations.

Figures 1 to 3 show the mean-midrange difference plotted against midrange, with the respective regression lines. Figure 1 is for the 12 months at Burbank, figure 2 for January and July at the other five stations, and figure

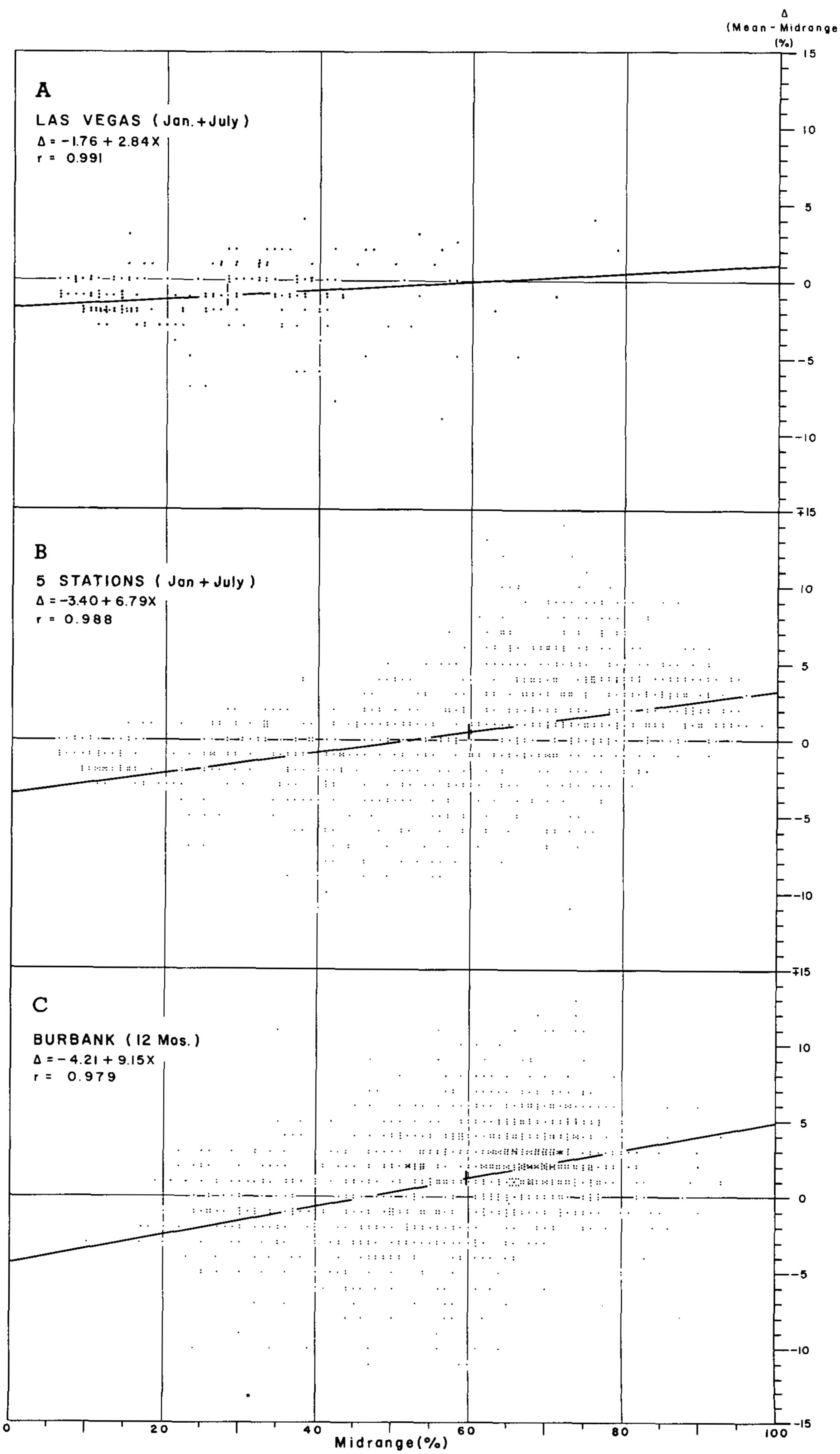

FIGURE 3.—Mean midrange difference of daily relative humidity vs. midrange, 1961–63, (A) for Las Vegas, Nev., in January and July, combined; (B) for 5 stations in January and July, combined; and (C) for Burbank, Calif., in all months.

3 consists of various combinations of the data in figures 1 and 2. In the linear regression

$$\Delta = a + bx,$$

Δ is the difference between mean and midrange, and x is the observed daily midrange. A linear relation was assumed, after trials tended to point in this direction. Correlation coefficients ($r_{x\Delta}$), telling how closely the variables Δ and x are related to each other on the regression line, are presented with each figure.

The original regression lines were computed to estimate mean from observed midrange. For convenience the lines were adjusted so that corrections could be read directly from the graphs. Algebraic addition of these corrections (Δ) to the observed midrange (x) gives the predicted value of the mean relative humidity.

5. ANALYSIS

The most striking similarities between the regression lines in figures 1 to 3 are their slopes and intercepts. In the 25 examples, 24 lines have positive slopes, 22 have Δ intercepts below the x axis, and 21 lines cross the x axis. In most cases the midrange underestimates the mean at high values of relative humidity and overestimates it at low values.

The few exceptions to these trends usually occur in samples confined within small ranges. At Nantucket in July, the only example in which the regression line slopes downward, only one-tenth of the midrange values are below 70 percent relative humidity and none below 60 percent. The other two cases with positive intercepts are at Burbank in June (average midrange 67.5 percent, standard deviation only 9.5) and at Jacksonville in January (midrange 71.6 percent, standard deviation 11.5). In these two cases, only about one day per month has a humidity midrange below 50 percent. At the other end of the scale, Las Vegas in July has the only case of a line with positive slope and negative intercept but which fails to cross the x axis. Here only one-twentieth of the humidities are greater than 30 percent.

That these apparent anomalies may be the result of fitting regression lines to a limited scatter of points is borne out by the results of the combined January and July regression for Las Vegas (fig. 3A). For this wider range of observations, the regression line crosses the x axis near 60 percent, which fits the general rule of low midrange readings at high humidities. Combining the January and July readings for all stations except Burbank (fig. 3B) smooths out the anomalies: the line fits very neatly, having a relatively steep slope and crossing the x axis near 50 percent.

The graphs for Burbank (figs. 1 and 3C) are perhaps the most revealing results of the study. In all the months except June the midrange underestimates the mean at high values and overestimates it at low values. The combination of the 12 months adheres closely to this principle, which can easily be seen in the scattering of points about the regression line in figure 3. In addition, the steepness of the slope shows a definite seasonal trend with maxima in both spring and fall and minima in summer and winter (fig. 1). This double maximum is unique: none of the parameters—yearly average humidity, standard deviation of the midrange and correction, or correlation—shows a similar seasonal trend.

TABLE 3.—*Corrections for midrange of relative humidity to fit the mean*

Midrange (%)	0–15	16–30	31–45	46–55	56–70	71–85	86–100
Correction to mean (%)	−3	−2	−1	−	+1	+2	+3

6. CONCLUSION

The results of this study, presented graphically for five stations in figure 3B, indicate that the midrange overestimates the mean for low values of relative humidity, and underestimates the mean for high values. Unless computation for individual stations shows otherwise, the corrections in table 3 may be used to adjust daily midrange values to the mean.

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